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13. ABSTRACT *(Maximum 200 words)*

THE PURPOSE OF THIS PAPER IS TO PROVIDE A GENERAL PERSPECTIVE ON HOW THE POTENTIAL FOR THE COST GROWTH WILL AFFECT THE ULTIMATE COST OF REMEDIATION AT RMA. THIS PAPER WILL UTILIZE DATA FROM RMA AND AROUND THE COUNTRY TO IDENTIFY THE FACTORS MOST LIKELY TO CAUSE COST GROWTH AT RMA. BECAUSE HISTORICAL DATA INDICATES THE REMEDIATION OF SOILS HAS THE HIGHEST POTENTIAL FOR COST GROWTH, COMPARED TO GROUNDWATER AND STRUCTURES, IT IS THE FOCUS OF THIS PAPER. IT SHOULD BE RECOGNIZED THAT THE REMEDIATION OF GROUNDWATER AND STRUCTURES ALSO HAS THE POTENTIAL TO ADD TO COST GROWTH AT RMA.

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EVALUATION OF POTENTIAL COST GROWTH AT RMA

Prepared by
MK-Environmental Services
Denver, Colorado 80203

Prepared for
Shell Oil
Denver, Colorado 80203

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1.0 INTRODUCTION

Developing accurate cost estimates for the remediation of Superfund sites has been a significant challenge for the engineering/construction community for the last decade. Hazardous waste site remediations have experienced significant cost growth that is higher than that associated with conventional engineering/construction projects. Historical data from the Rocky Mountain Arsenal (RMA) and other Superfund sites show that the potential for cost growth has generally been significantly underestimated at the Record of Decision (ROD) stage.

In recent years, several cost engineers have devised different approaches to attempt a more accurate characterization of cost uncertainties. This is an extremely important factor at RMA because failure to accurately address cost uncertainty could result in significant cost differences, between the preliminary cost estimates of alternatives and final remediation costs.

The purpose of this paper is to provide a general perspective on how the potential for cost growth will affect the ultimate cost of remediation at RMA. The paper will utilize data from RMA and around the country to identify the factors most likely to cause cost growth at RMA. Because historical data indicates the remediation of soils has the highest potential for cost growth, compared to groundwater and structures, it is the focus of this paper. It should be recognized that the remediation of groundwater and structures also has the potential to add to cost growth at RMA.

Historical data from RMA and other hazardous waste sites will be used to approximate the ranges of the potential for cost growth (contingency) associated different types of remedial action for soils. This information will then be used to evaluate the

relative cost uncertainty for 2 remedial scenarios (Scenarios #1 and #5) being considered in the Detailed Analysis of Alternatives (DAA) to illustrate the relative potential for cost growth for remedies involving considerable excavation/treatment versus remedies which are predominately containment approaches.

A significant amount of money has been spent to date at RMA (about $750 million) on the Remedial Investigation/Feasibility Study (RI/FS), Ground Water Boundary/Treatment Systems, the Basin F Submerged Quench Incinerator (SQI) and other Interim Response Actions (IRAs). Although continuation of these remediation programs may also be a source of potential cost growth, only the final alternatives for soils in the DAA are discussed in this paper.

2.0 NATIONAL PERSPECTIVE ON POTENTIAL COST GROWTH AT HAZARDOUS WASTE SITES

There is substantial information in the literature about the problems associated with accurately predicting remediation costs at U.S. hazardous waste sites (Doty et al., 1991, GAO, 1988, GAO, 1992c, GAO, 1994a, Hudson et al., 1990, Morse, 1993, Richardson et al., 1990, Russell et al., 1991, Schroeder, 1990, Schroeder et al., 1990). Many of the articles take a national view of the total funds required to remediate hazardous waste sites across the United States. Most of these articles have been produced by the General Accounting Office (GAO). Because the focus of these articles is generally to provide information to Congress on funding requirements, the sites are often grouped as to whether they are funded by Department of Defense (DOD), Department of Energy (DOE), EPA or some other government agency. These articles are very useful in discerning the unique characteristics of each group of sites (DOD, DOE, etc.) and the impact of these characteristics on cost growth.

Other articles (those other than GAO articles) have focused more on identifying the specific factors that have contributed to cost growth at completed hazardous waste sites. For example, many of these articles provide data on cost growth for different general types of remedies (i.e., containment, excavation/disposal and excavation/treatment). Other articles have related cost uncertainty to the design stage (ROD versus Remedial Design (RD) versus construction bid) of the project. Both groups of articles provide insight into the cost growth issue at RMA and the main factors influencing cost growth will be discussed in greater detail below.

2.1 PROJECT DEFINITION

The most important factor influencing cost uncertainty is project definition (DOE, 1991, Schroeder et al., 1990). Project definition is the process of defining what will be done, how it will be done, who will do it, when it will be done, and what resources will be needed. Generally, project definition is developed during the RI/FS and RD stage on Superfund projects. As the project progresses through these phases, project definition generally increases. Case histories show that estimates from early in the Superfund process (i.e., pre-ROD and ROD estimates) have been subject to the highest cost growth. As projects progress through the RD stage, estimates generally improve and the potential for cost growth declines.

A common misconception, however, is that completion of RI/FS adequately defines the remediation project for accurate cost estimation. This is because the RI/FS phase is often more concerned with meeting objectives such as human health risks or ARARs identification, rather than defining the project in terms of engineering/construction (DOE, 1993). Because of its sheer size and complexity, large sites such as RMA generally have inherently less project definition than smaller sites containing fewer contaminated areas, fewer contaminants and less heterogeneous media (not homogeneous, dissimilar contaminant concentrations throughout). Also, environmental projects have fundamentally less project definition than more conventional design/construction projects because they are a relatively new class of projects and these projects usually deal with subsurface conditions for which there are always inherent uncertainties. Lack of project definition, more than any other single factor, is likely to have a significant impact on cost growth.

2.2 SITE SIZE AND COMPLEXITY

Most of the Superfund sites where remediation has been completed are relatively small relative to RMA and other federal Superfund facilities (GAO, 1992b, GAO, 1993a and GAO, 1994b). The time lag for completion of large and complex sites is primarily because of the much longer periods of time for these complex sites to get through the RI/FS and RD/Remedial Action (RA) process. For example, Richardson et al. (1990) examined the cost growth at 44 completed Superfund sites. The average total construction costs for these sites was less than $5 million. The lowest estimated remedial cost in the DAA for any remedial scenario at RMA is $860 million (see Table 1, Scenario #2 Cost for Soil, Water and Structures) or more than 170 times the average cited by Richardson. Although the Army discusses potential cost growth in the DAA, there was no attempt to quantify it and the costs in Table 1 only contain conventional construction contingencies. Although data from earlier sites is meaningful, it must be used with care when extrapolating to much larger and complex sites such as RMA.

Although early studies by Schroeder (1990) indicate cost uncertainty (i.e., on a percentage basis) is not particularly sensitive to site size, the authors caution the use of this preliminary conclusion because of the relative absence of large sites in their data base. Despite this, relatively modest cost growth (i.e., on a percentage basis) can result in extreme absolute cost growth because of the sheer magnitude of the site. For example, 50% cost growth on a $5 million site is $2.5 million, by contrast, 50% cost growth for the lowest RMA estimate ($860 million) would be $430 million. These examples illustrate that cost growth of only a few percentage points at RMA will result in significant cost growth.

Site complexity refers to features such as different combinations and concentrations of contaminants, different contaminated media and heterogeneous site conditions. Researchers have found that increased site complexity increases the potential for cost growth (DOE, 1991). Because of the number of contaminants of concern at RMA (from pesticides to chemical agents), the different media involved (soils, water and structures) and its heterogeneity and size (widely varying concentrations and 27 square miles), RMA is considered a very complex and large site and this requires consideration when attempting to estimate the potential for cost growth.

2.3 CONTAINMENT VERSUS EXCAVATION/TREATMENT

Another national issue affecting cost uncertainty is the preference for treatment in the Superfund Amendments Reauthorization Act (SARA) of 1986 (GAO, 1988). The majority of sites that were in the remediation process prior to SARA were either contained or used disposal as the primary elements of remediation (GAO, 1988, Richardson et al., 1990). Data has shown that complex excavation/treatment technologies have much higher potential for cost growth than containment remedies due to volume growth, and uncertainty about the scope and application of the technology (GAO, 1988, GAO, 1993b, Richardson et al., 1990, Russell et al., 1991 and Schroeder et al., 1990, Schroeder, 1990). Containment technologies are generally more representative of routine construction projects and are generally not sensitive to the factors that cause cost growth on complex excavation/treatment technology sites.

2.4 PRIVATE SECTOR VERSUS GOVERNMENT MANAGEMENT

Another factor that can influence cost growth is whether management of the remedial actions is conducted by government or private-sector entities. Data have shown (see Figure 1) that the average cost growth at Federal-lead Superfund sites is 75% compared to about 10% on private-sector-lead projects. The reasons for this have largely been related to better project definition and more efficient management under the private-sector (Curtis, 1989, DOE, 1991; Schroeder et al., 1990). This historically high cost growth is relevant to RMA since it is a Federal-lead Superfund site.

2.5 DELAYS DUE TO REGULATORY AND COMMUNITY CONCERN ISSUES

Another set of factors which can significantly impact cost growth, are the effects of regulatory and community issues. These can result from delays related to regulatory issues (e.g., stop work actions, changing requirements, different interpretation of existing regulations, changing staff, etc.) and community concerns. Although documented in the literature as a significant source of cost uncertainty (Schroeder, 1990), historical data from other remediation sites are of little use in estimating the costs of the changes resulting from regulatory issues. This is because of the unique site-specific issues (the exact identity of responsible parties, regulators and community) that influence these potential changes. The best means of evaluating potential cost growth from this factor is to use any experience gained from previous interim response or removal actions conducted at the site.

3.0 SPECIFIC COST GROWTH CATEGORIES

The discussion in Section 2.0 focused on identifying the factors, such as lack of project definition and the complexity of a treatment process, that generally lead to cost growth. In order to understand cost growth at hazardous waste sites, it is important to have a basic understanding of how these factors actually translate into increased costs. A brief explanation is provided below.

The estimated cost of a particular remedy can be developed by multiplying two basic components:

- The unit cost (e.g., $/ton, $/cubic yard, etc.); and
- The amount (tons, cubic yards, etc.) to be treated.

The changes in unit cost of a remediation alternative can be divided into smaller components which, when summed, provide the total change in unit cost. These components can be broken out as follows:

- Unit Cost Changes Due to Scope Changes. The design of the remediation undergoes process modifications or additions, or changes in technology that result in a change in the unit cost.

- Unit Cost Changes Due to Technology Application Uncertainty. The unit cost of applying the technology changes even though the design remains unchanged. For example, if the throughput of thermal treatment unit is decreased for air emission reasons, this would increase project duration and operating costs even though the design has remained unchanged.

- Unit Cost Changes Due to Regulatory, Community Concerns. The final project design and construction and operational plans can undergo changes in responses to regulatory or community concerns which were not anticipated at the pre-engineering stage.

The other major component of cost growth, in addition to unit cost growth, is cost growth due to volume growth (Richardson et al., 1990). This is when the quantity of contaminated material requiring remediation changes from estimates developed earlier in the process. For example, even if the unit cost (e.g., $/ton) of a technology remains constant, the total cost of an alternative would roughly double if the tonnage to be treated doubles.

The following section will provide some historical data from U.S. remediation projects, including RMA, that provide a basis for estimating ranges of total cost growth. In most cases total cost growth data is reported because data were not sufficient to provide further breakout. There is, however, some data available on volume cost growth and this information has been provided where available.

4.0 DEVELOPMENT OF POTENTIAL COST GROWTH RANGES FOR RMA

The following sections will provide the basis for development of ranges of contingency (i.e., potential cost growth) for different types of remedies at RMA. In general, there is some historical data (about 10 sites for each category) on cost growth for completed remedies involving excavation/disposal, containment and in situ and ex-situ treatment sites.

Containment and in situ technologies have been discussed together in Section 4.1. There is very little potential for volume cost growth with these two types of remedy. However, in situ technologies are subject to much higher unit cost growth than containment technologies because of longer than predicted cleanup times.

The cost growth associated with excavation, treatment and landfilling is discussed in Section 4.2. There are enough historical data to breakout volume cost growth for this category of remedy and so a separate discussion has been devoted to this component.

Where possible, data for cost growth was obtained from estimates contained in the ROD, to project completion. It should be noted that contingencies (potential cost growth) are generally for total costs which includes direct and indirect costs. Direct costs are costs incurred by contractors and subcontractors to actually perform activities such as construction and operation of treatment plants, perform excavation and construction of landfills. Indirect costs are typically 40% to 100% (higher for complex technologies) of direct costs and include items such as engineering, overhead, construction management, additional treatability tests, and profit. As will be discussed in Section 5, some additional contingency has been added to high technology

treatment remedies to account for the additional indirect costs often incurred.

4.1 CONTAINMENT AND IN SITU TECHNOLOGIES

4.1.1 Total Cost Growth

Total cost growth data for containment and in situ technologies are summarized in Table 1. Schroeder's and Shangraw's (1990) evaluation of 40 sites indicates that total cost growth for sites using containment technologies averaged about 48%. This figure, however, includes the basic 15% to 25% contingency used in most construction estimates indicating that the actual cost growth was from about 23% to 33%.

Richardson (1990) cited total cost growth data from 6 containment remedy sites. The average total cost growth at these sites was approximately 33%.

Doty et al., (1991), however, showed that there was an average of 160% increase in total capital costs for 3 sites using in situ technologies. This included 2 vapor extraction sites and 1 biodegradation site. Most of the increase was attributed to underestimation of contaminant levels and longer operating times. The authors note, however, that none of these projects have been completed and cost growth could go even higher.

There is significant data from RMA that show that the potential for total cost growth for containment technologies is small relative to complex treatment technologies and is comparable to that of conventional design/construction projects (Richardson et al., 1990, Schroeder and Shangraw, 1990). Two predominantly containment projects performed at RMA, the Northwest Boundary Slurry Wall extension and Shell Trenches Slurry Wall and Soil

Cover, have been conducted in the last 5 years. These projects were estimated using contingencies from about 15% to 25%. These projects were implemented under typical industrial design and construction contracting practices and were completed within -1 to 16% of the original Decision Document budgets as shown in Table 2. Since these activities are comparable to the containment activities envisioned in the DAA alternatives, these site-specific data would confirm that there is minimal potential for cost growth associated with this type of containment activities.

4.2 EXCAVATION/TREATMENT TECHNOLOGIES

4.2.1 Volume Cost Growth for Excavation

Average volume cost growth data is summarized in Table 3. Richardson et al., (1990) provided cost growth figures from the ROD stage for nine soil excavation projects and two projects which involved excavation of drums/barrels. In all cases, Richardson reported that the project managers said cost growth was due to volume uncertainty (i.e., having to excavate substantially more than estimated at the ROD). The volume cost growth from these sites typically averaged 66% to 75%.

Doty et al., (1991) reported on final versus ROD estimated remediation costs at 14 sites involving ex-situ treatment. It should be noted, however, that 7 of these 14 sites have not been completed. These results show an average of 64% volume increase for the 14 ex-situ technologies (Table 3).

At RMA, only one previous action has involved the excavation of substantial amounts of contaminated material, the Basin F Waste Pile IRA. This project experienced volume cost growth of about 50% from the initial construction bid. Also, since this was an

IRA, the initial estimate was more of a construction estimate which have been shown to show less cost growth than ROD (conceptual engineering) estimates. A more detailed breakout on cost growth for this project is provided in Table 5.

In summary, historical data indicate the range of potential volume cost growth for excavation activities may be expected to range up to 170% with average values in the 50% to 75% range.

4.2.2 Total Cost Growth Data for Excavation and Treatment

Total cost growth data for excavation/treatment sites has been reported by several authors and is summarized in Table 4. Doty et al., (1990) reported total cost growth according to low-intensity and high-intensity treatment. The total average low-intensity cost growth was 96% for the 8 sites examined. However, total cost growth on the 5 sites which were actually completed was 123%. These data also show that low-technology ex-situ remedies, such as stabilization, exhibit less cost growth than complex technologies like dechlorination or low-temperature thermal treatment.

Only 2 of the 6 high intensity sites were complete and the average cost growth for them was 137%. The 6 high intensity treatment sites (incineration), including 4 uncompleted sites, exhibited average cost growth of 30%.

Schroeder and Shangraw (1990) showed that the average total cost growth at sites using treatment was about 55%. However, they do not differentiate between soil and water treatment.

Both an excavation/disposal and a treatment project at RMA (Basin F IRA and the Submerged Quench Incinerator) show that there was substantial cost growth associated with these projects.

The SQI IRA cost growth was due to items not included in the original budget such as off-site disposal of brine, RCRA closure, capital and operating cost increases and substantial risk assessment issues. These changes resulted in cost growth in the range of 320% to 420% from the conceptual estimate (see Table 5).

The Basin F Liquid and Sludges IRA also experienced cost growth not due to volume changes. This growth was a result of items such as constructing a double versus a single liner waste pile, more complex excavation and abandonment of a pug mill for mixing material. It is estimated that these changes in scope resulted in additional (unit cost growth) growth of about 45% (see Table 5).

5.0 POTENTIAL COST GROWTH FOR SCENARIOS #1 AND #5

The available data from RMA and other sites is unanimous in showing that contingencies (Note: the term **contingency** will be used instead of potential for future cost growth for the remainder of the document) used for conventional engineering/ construction will result in an underestimate of costs at the conceptual engineering stage. There is engineering judgment required in developing more appropriate contingency ranges for each type of remediation. The contingency ranges have been left quite broad to reflect the approximate nature of the estimates. The contingencies were based on the following assessment of site-specific factors at RMA:

- The RMA is a Federal-lead Superfund site and a majority of the remediation will be conducted under Army management;
- Project definition is at the Pre-ROD conceptual engineering stage;
- RMA is a large and complex site relative to Superfund sites which have been completed to date;
- There is a relatively high probability of delays on remedial actions due to regulatory and community issues.

The ranges of unit cost and volume contingencies believed to be reasonable for RMA are summarized in Table 6. These contingencies have been separated into: containment; in situ treatment; excavation/ex-situ treatment/landfill; excavation/ stabilization/landfill; and excavation/landfill remedies as discussed above. These groups of technologies have been assigned different contingency ranges based on the data in the literature. The contingencies were assigned so that the low end contingency

corresponds to typical engineering/construction contingencies (25% to 60%), the middle value to approximate averages of historical cost growth data and the high end to the highest historical cost growth data.

Based on Table 2, the range of contingencies used for containment was from 20% to 100%. A value of 50% was used for the historical average. The only available data for in situ remedies indicated that average total cost growth could be as high as 160%. Because only 3 sites were used to obtain this figure, two showed only slight cost growth and none were really comparable to agricultural practices, a high end contingency of 60% was used for the in situ (agricultural practices) technologies.

Contingencies for excavation and thermal treatment technologies were derived from Tables 3 and 4. A contingency of 75% was chosen as the middle range value for volume uncertainty and unit cost uncertainty, resulting in a total middle range contingency of 150%. This figure is just above that seen historically at completed treatment sites but substantially lower than that observed for the Basin F SQI IRA. The high end contingencies for volume and unit cost were selected as 170% and 100%, respectively. Additional contingencies for indirects of 10% to 50% were used to account for higher engineering and construction management costs on this type of project compared to more conventional engineering/construction projects. This results in a total contingency of 60% to 320% for this class of technology.

Excavation/stabilization/landfill and excavation/landfill technologies were assigned slightly lower contingencies from 50% to 230%, based upon data from Doty et al., (1990), that showed that stabilization had relatively little cost growth potential compared to just excavation/landfilling.

The purpose of developing this range of contingencies is to provide a basis for evaluating the relative cost growth potential (contingency) between Scenarios #1 and #5 so that more informed decisions can be made with regard to final cost. These contingencies have been allocated to each medium group for Scenarios #1 and #5 as shown in Tables 7 and 8, respectively.

The relative differences in potential cost growth for soils remediation between different alternatives #1 and #5 are provided in Tables 9 and 10. Scenarios #1 and #5 represent a primarily containment alternative and an alternative involving substantial excavation and treatment, respectively. These examples provide some perspective on the relative importance of the potential cost growth issue for these two general types of remedy.

6.0 CONCLUSIONS

It is apparent from Tables 9 and 10 that the potential cost growth is significantly higher for Scenario #5 compared to Scenario #1. Scenario #5 has the potential for about $1.8 billion in cost growth compared to about $325 million for Scenario #1 based on historical data from some of the highest cost growth sites. This finding is not surprising and is consistent with response action experience at RMA and all the available literature from RMA and other U.S. Superfund sites because of significantly more excavation and complex treatment in Scenario #5. In short, the risk of cost growth is substantially less for a remedy similar to Scenario #1 compared to Scenario #5. The total cost of Scenario #5 under the high contingency scenario would be greater than $5 billion.

The RMA us a unique site in terms of size, complexity and regulatory environment compared to Superfund sites which have been completed to date. It seems likely that these factors will drive cost growth higher than the historical averages observed at smaller, less complicated sites. This seems particularly true of excavation/treatment remedies which have already been observed to exhibit extreme cost growth at RMA.

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TABLE 1. TOTAL ESTIMATED REMEDIATION COSTS FOR RMA FROM ARMY DAA (1995 MILLIONS OF DOLLARS)*

	SITEWIDE SOIL ALTERNATIVES				
COST ELEMENT	**1**	**2**	**3**	**4**	**5**
Soil**	$520	$380	$650	$630	$1,000
Water	$270	$270	$270	$270	$270
Structures	$210	$210	$210	$210	$210
Pre-ROD Costs	$750	$750	$750	$750	$750
PMRMA Mission Support	$315	$270	$315	$405	$630
Total Cost	**$2.1 billion**	**$1.9 billion**	**$2.2 billion**	**$2.3 billion**	**$2.9 billion**

*All Army cost figures used conventional construction contingencies and do not allow for potential cost growth.

**All costs in 1994 dollars, not adjusted for inflation.

TABLE 2. TOTAL COST GROWTH FOR CONTAINMENT AND IN SITU REMEDIES

NUMBER AND TYPE REMEDIATION	COST GROWTH RANGE	AVERAGE COST GROWTH
40[a,b,c] (containment)	N/A	48%[d]
6[e] (containment)	-35% to +105%	33%
3[f] (in situ remediation)	0%-421%	160%
2[g] (containment at RMA)	-1%-16%	8%

N/A Not Available

[a]Schroeder and Shangraw, 1990.

[b]40 sites total, an unknown percentage were containment remedies.

[c]Cost growth from remedial design/construction estimate.

[d]Cost growth after removal of contingency.

[e]Richardson et al., 1990.

[f]Doty et al., 1990, based on contracted cost.

[g]Shell Trenches and Northwest Boundary Extension.

TABLE 3. VOLUME COST GROWTH DATA FOR EXCAVATION REMEDIES

NUMBER AND TYPE SITE	COST GROWTH RANGE	AVERAGE COST GROWTH
9 Soil Excavation[a]	4% to 170%	75%
2 Drum/Barrel Excavation[a]	1% to 131%	66%
14 Excavation/Treatment[b]	N/A	63%*
1 Basin F Liquid/Sludges IRA	-----	50%

*Assumes cost growth due to volume increase is directly proportional to volume increase.

N/A Not available.

[a]Richardson et al., 1990.

[b]Doty et al., 1991.

TABLE 4. TOTAL COST GROWTH DATA FOR EXCAVATION/TREATMENT TECHNOLOGIES

NUMBER AND TYPE SITE	COST GROWTH RANGE	AVERAGE TOTAL COST GROWTH
8 Low Intensity/Treatment[a]	53% to 584%	96% (123%)[b]
6 High Intensity/Treatment[a]	-56% to 330%	33% (137%)[c]
1 Basin F Liquids Incinerator		320% to 420%
40 Sites[d]	-----	55%

[a]Doty et al., 1991, noted only 7 of these sites were completed, includes 6 incineration, 6 stabilization, 1 low-temp thermal, 1 dechlorination.

[b]Cost growth in parentheses is for 5 completed sites.

[c]Cost growth for 2 completed sites.

[d]Shangraw and Schroeder, 1990. An unknown portion of the 40 sites were soils treatment.

TABLE 5. RMA COST GROWTH EXAMPLES

	SQI IRA (Conceptual Est.)	BASIN F IRA (Contractor Bid)
TOTAL COST GROWTH	19 MM to 80-100 MM	23 MM to 45 MM
UNIT COST GROWTH BY CATEGORY		
1. Scope Definition	Est. 180-220% (Offsite disposal, brine shipment system, RCRA closure)	Est. 45% (Double liner, more comp excavation, abandonmen of pug mill)
2. Technology Application	Est. 100-140% (SQI technology capital $ increase)	0
3. Regulatory Delays/Litigation	Est. 40-60% (Risk assessment, increase in number of mini/trial burns, lower throughput)	Incorporated under Scope Definition
VOLUME COST GROWTH	0	Est. 50%
Total Cost Growth %	Est. 320%-420%	Est. 95%

TABLE 6. CONTINGENCY SUMMARY

REMEDY TYPE	UNIT COST CONTINGENCY (%)	VOLUME CONTINGENCY (%)	ADDITIONAL INDIRECTS (%)	TOTAL (%)
Containment (capping, slurry walls, plugging sources)	20-50-100	0	0	20-50-100
In situ treatment (agricultural practices)	25-50-60	0	0	25-50-60
Excavation ex-situ treatment/ landfill (thermal treatment)	25-75-100[a]	25-75-170	10-30-50	60-180-320
Excavation/stabilization/landfill (caustic stabilization)	25-50-60[b]	25-75-170	0	50-125-230
Excavation/landfill	25-50-60	25-75-170	0	50-125-230

[a]200-250-300% were used for excavation of Shell Trenches because of extremely difficult excavation conditions.

[b]Unit cost uncertainty due only to uncertainty associated with excavation, because ex-situ stabilization processes have shown little historical cost growth.

TABLE 7. CONTINGENCY BY MEDIUM GROUP FOR SCENARIO 1

SOIL MEDIUM GROUP/SUBGROUP	UNIT COST(%)	VOLUME(%)	INDIRECT(%)	TOTAL(%)
MUNITIONS TESTING	25-50-60	25-75-170	0	50-125-230
NORTH PLANTS	25-50-60	25-75-170	0	50-125-230
TOXIC STORAGE YARDS	25-50-60	25-75-170	0	50-125-230
LAKE SEDIMENTS	25-50-60	25-75-170	0	50-125-230
SURFICIAL SOILS (BASIN F EXTERIOR)	25-50-60	25-75-170	0	50-125-230
DITCHES/DRAINAGE AREAS	0	0	0	0
BASIN A	25-50-100	0	0	25-50-100
BASIN F WASTEPILE	25-50-100	0	0	25-50-100
SECONDARY BASINS	25-50-100	0	0	25-50-100
FORMER BASIN F	25-50-100	0	0	25-50-100
SANITARY/PROCESS WATER SEWERS	25-50-100	0	0	25-50-100
CHEMICAL SEWERS	25-50-100	0	0	25-50-100
COMPLEX TRENCHES	25-50-100	0	0	25-50-100
SHELL TRENCHES	25-50-100	0	0	25-50-100
HEX PITS	25-50-100	0	0	25-50-100
SANITARY LANDFILL	25-50-100	0	0	25-50-100
SECTION 36 LIME BASIN	25-50-100	0	0	25-50-100
BURIED M-1 PITS	25-50-100	0	0	25-50-100
SOUTH PLANTS CENTRAL PROCESSING	25-50-100	0	0	25-50-100
SOUTH PLANTS DITCHES	25-50-100	0	0	25-50-100
SOUTH PLANTS BALANCE OF AREAS AND SOUTH PLANTS TANK FARM	25-50-100	0	0	25-50-100
BURIED SEDIMENTS	25-50-100	0	0	25-50-100
SAND CREEK LATERAL	25-50-100	0	0	25-50-100
SECTION 36 BALANCE OF AREAS	25-50-100	0	0	25-50-100
BURIAL TRENCHES	25-50-60	25-75-170	0	50-125-230

TABLE 8. CONTINGENCY BY MEDIUM GROUP FOR SCENARIO 5

SOIL MEDIUM GROUP/SUBGROUP	UNIT COST(%)	VOLUME(%)	INDIRECT(%)	TOTAL(%)
MUNITIONS TESTING	25-50-60	25-75-170	0	50-125-230
NORTH PLANTS	25-50-60	25-75-170	0	50-125-230
TOXIC STORAGE YARDS	25-50-60	25-75-170	0	50-125-230
LAKE SEDIMENTS	25-50-60	25-75-170	0	50-125-230
SURFICIAL SOILS (BASIN F EXTERIOR)	25-50-60	0	0	25-50-60
DITCHES/DRAINAGE AREAS	25-50-60	25-75-170	0	50-125-230
BASIN A	25-50-60	25-75-170	0	50-125-230
BASIN F WASTEPILE	25-75-100	25-75-170	10-30-50	60-180-320
SECONDARY BASINS	25-50-60	25-75-170	0	50-125-230
FORMER BASIN F	25-75-100	25-75-170	10-30-50	60-180-320
SANITARY/PROCESS WATER SEWERS	25-50-100	0	0	25-50-100
CHEMICAL SEWERS	25-75-100	25-75-170	10-30-50	60-180-320
COMPLEX TRENCHES	25-50-100	0	0	25-50-100
SHELL TRENCHES	200-250-300	25-75-170	10-30-50	235-355-520
HEX PITS	25-75-100	25-75-170	10-30-50	60-180-320
SANITARY LANDFILL	25-50-60	25-75-170	0	50-125-230
SECTION 36 LIME BASIN	25-50-60	25-75-170	0	50-125-230
BURIED M-1 PITS	25-50-60	25-75-170	0	50-125-230
SOUTH PLANTS CENTRAL PROCESSING	25-75-100	25-75-170	10-30-50	60-180-320
SOUTH PLANTS DITCHES	25-50-60	25-75-170	0	50-125-230
SOUTH PLANTS BALANCE OF AREAS AND SOUTH PLANTS TANK FARM	25-50-60	25-75-170	0	50-125-230
BURIED SEDIMENTS	25-50-60	25-75-170	0	50-125-230
SAND CREEK LATERAL	25-50-60	25-75-170	0	50-125-230
SECTION 36 BALANCE OF AREAS	25-50-60	25-75-170	0	50-125-230
BURIAL TRENCHES	25-50-60	25-75-170	0	50-125-230

POTENTIAL COST GROWTH FOR SOILS - SCENARIO NO. 1

TABLE 9

MEDIUM GROUP OR SUBGROUP	ALTERNATIVE	EXCEEDANCE VOLUME (BCY)			COST SUMMARY (1994 DOLLARS IN MILLIONS)							
					ARMY	ARMY EST.	% CONTINGENCY			SHELL		
		P.T.	H.H.	BIOTA	ESTIMATE	W/O CONT.	LOW	AVG	HIGH	LOW	AVG	HIGH
MUNITIONS TESTING	Detonation (U)/LF				$9.6	$7.4	50	125	230	$11.1	$16.6	$24.4
NORTH PLANTS	Caustic (A)/LF(H)		157	16,494	$0.9	$0.7	50	125	230	$1.0	$1.5	$2.2
TOXIC STORAGE YARDS	Caustic (A)/LF(H)		349	18,466	$2.8	$2.2	50	125	230	$3.2	$4.9	$7.1
LAKE SEDIMENTS	LF (H)		16,427	23,000	$2.4	$1.8	50	125	230	$2.8	$4.2	$6.1
SURFICIAL SOILS [Basin F Exterior]	LF (H)	1,500	89,612	2,700,000	$7.7	$5.9	50	125	230	$8.9	$13.3	$19.6
DITCHES/DRAINAGE AREAS	No Action			52,000								
BASIN A	Cap (H/B)	34,000	180,000	120,000	$59.0	$45.4	25	50	100	$56.8	$68.1	$90.9
BASIN F WASTEPILE	RCRA Cap (H)	580,000	580,000		$24.0	$18.5	25	50	100	$23.1	$27.7	$37.0
SECONDARY BASINS	Cap (H/B)		32,000	170,000	$45.0	$34.7	25	50	100	$43.3	$52.0	$69.3
FORMER BASIN F	RCRA Cap	179,063	681,651		$38.0	$29.3	25	50	100	$36.6	$43.9	$58.5
SANITARY/PROCESS WATER SEWERS	Plug Manholes (H)				$0.7	$0.5	25	50	100	$0.7	$0.8	$1.1
CHEMICAL SEWERS	Plug Sewers (H)	47,000	82,000		$3.5	$2.7	25	50	100	$3.4	$4.0	$5.4
COMPLEX TRENCHES	Cap/S.W. (H/B)	440,000	450,000	89,537	$38.0	$29.3	25	50	100	$36.6	$43.9	$58.5
SHELL TRENCHES	Mod.Cap/S.W. (H)	100,000	100,000		$4.0	$3.1	25	50	100	$3.9	$4.6	$6.2
HEX PITS	Cap/S.W. (H)	3,300	3,300		$1.7	$1.3	25	50	100	$1.6	$2.0	$2.6
SANITARY LANDFILL	Cap (H)		400,000	16,000	$13.0	$10.0	25	50	100	$12.5	$15.0	$20.0
SECTION 36 LIME BASINS	Clay/Soil Cap Site	9,727	54,151		$4.7	$3.6	25	50	100	$4.5	$5.4	$7.2
BURIED M-1 PITS	Cap/S.W. (H)	22,000	25,716		$2.7	$2.1	25	50	100	$2.6	$3.1	$4.2
SOUTH PLANTS CENTRAL PROCESSIN	Cap (H/B)	234,930	282,597	3,669	$26.0	$20.0	25	50	100	$25.0	$30.0	$40.0
SOUTH PLANTS DITCHES	Cap (H/B)	3,411	33,633	23,433	$11.0	$8.5	25	50	100	$10.6	$12.7	$16.9
SOUTH PLANTS BALANCE [Tank Farm]	Cap (H/B)	16,548	134,298	526,715	$140.0	$107.8	25	50	100	$134.8	$161.7	$215.6
BURIED SEDIMENTS	Cap (H)		16,000	7,900	$4.3	$3.3	25	50	100	$4.1	$5.0	$6.6
SAND CREEK LATERAL	Cap (H/B)		15,000	34,000	$18.0	$13.9	25	50	100	$17.3	$20.8	$27.7
SECTION 36 BALANCE OF AREAS	Cap (H/B)		79,000	140,000	$52.0	$40.0	25	50	100	$50.1	$60.1	$80.1
BURIAL TRENCHES	LF (H)		27,253		$8.9	$6.9	50	125	230	$10.3	$15.4	$22.6
	TOTAL	1,671,000	3,283,000	3,941,000	$517.9	$398.8				$504.7	$616.8	$829.8

▭ = Volume not addressed in DAA; obtained directly from Foster Wheeler.

Notes:
1. Excavations backfilled w/ clean borrow materials and revegetated.
2. Contingency estimate components include unit cost and volume contingency and additional indirects.

POTENTIAL COST GROWTH FOR SOILS - SCENARIO NO. 5

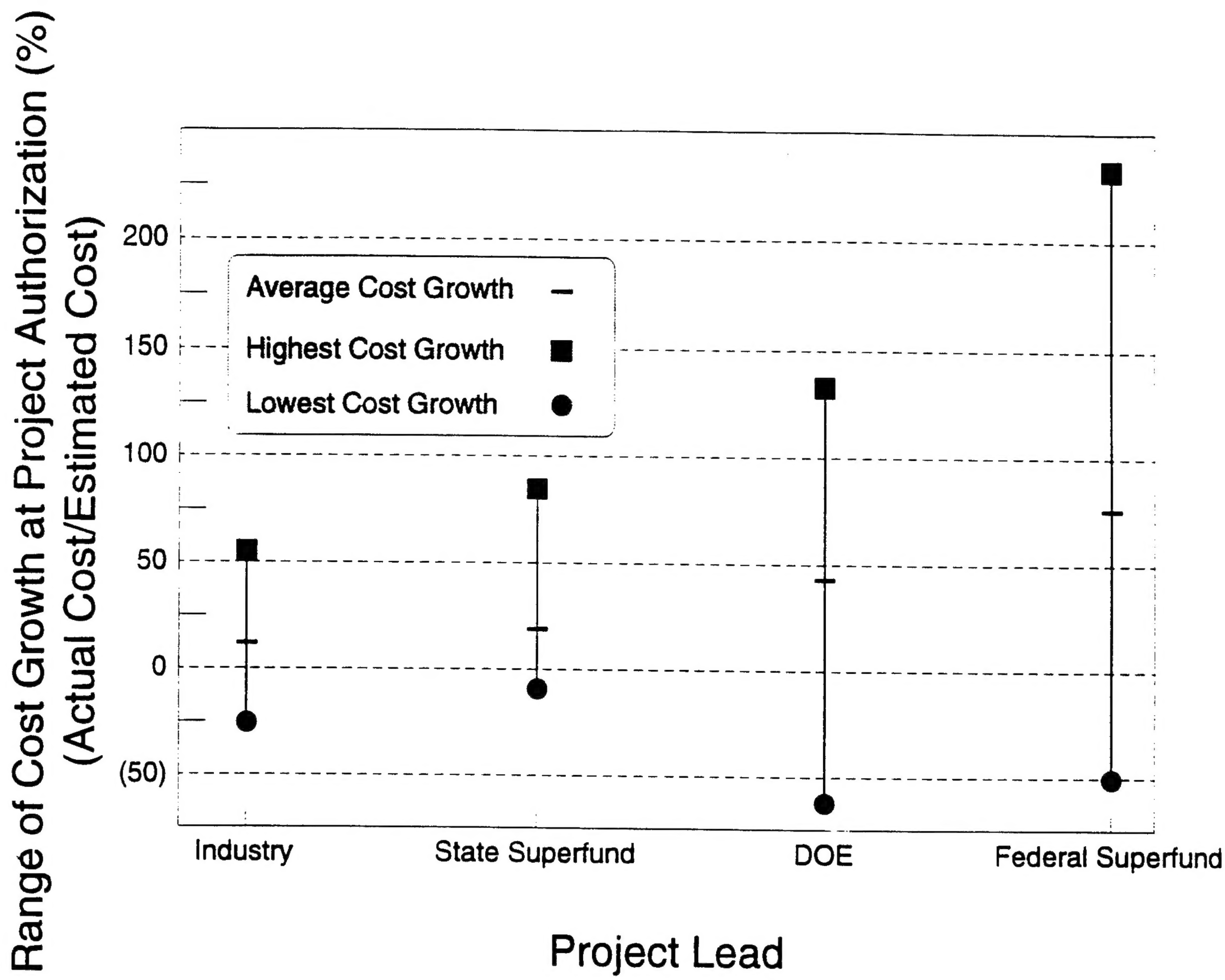
TABLE 10

MEDIUM GROUP OR SUBGROUP	ALTERNATIVE	EXCEEDANCE VOLUME (BCY)			COST SUMMARY (1994 DOLLARS IN MILLIONS)							
					ARMY	ARMY EST.	% CONTINGENCY			SHELL		
		P.T.	H.H.	BIOTA	ESTIMATE	W/O CONT.	LOW	AVG	HIGH	LOW	AVG	HIGH
MUNITIONS TESTING	Detonation (U)/LF				$8.4	$6.5	50	125	230	$9.7	$14.6	$21.3
NORTH PLANTS	Caustic (A)/LF(H)		157	16,494	$0.9	$0.7	50	125	230	$1.0	$1.6	$2.3
TOXIC STORAGE YARDS	Caustic (A)/LF(H)		349	18,466	$2.7	$2.1	50	125	230	$3.1	$4.7	$6.9
LAKE SEDIMENTS	LF (H/B)		16,427	23,000	$5.8	$4.5	50	125	230	$6.7	$10.0	$14.7
SURFICIAL SOILS [Basin F Exterior]	Ag. Prac.(B)/LF(H)	1,500	89,612	2,700,000	$12.0	$9.2	25	50	60	$11.6	$13.9	$14.8
DITCHES/DRAINAGE AREAS	LF (B)			52,000	$4.5	$3.5	50	125	230	$5.2	$7.8	$11.4
BASIN A	TD (PT)/LF (H)/Cap Site	34,000	180,000	120,000	$89.0	$68.5	50	125	230	$102.8	$154.2	$226.1
BASIN F WASTEPILE	TD-LF (H)	580,000	580,000		$240.0	$184.8	60	180	320	$295.7	$517.4	$776.2
SECONDARY BASINS	LF (H/B)		32,000	170,000	$15.0	$11.6	50	125	230	$17.3	$26.0	$38.1
FORMER BASIN F	TD (PT)/LF (H)/Cap Site	179,063	681,651		$220.0	$169.4	60	180	320	$271.0	$474.3	$711.5
SANITARY/PROCESS WATER SEWERS	Plug Manholes (H)				$0.7	$0.5	25	50	100	$0.7	$0.8	$1.1
CHEMICAL SEWERS	TD (PT)/LF (H)	47,000	82,000		$27.0	$20.8	60	180	320	$33.3	$58.2	$87.3
COMPLEX TRENCHES	Cap/S.W. (H/B)	440,000	450,000	89,537	$39.0	$30.0	25	50	100	$37.5	$45.0	$60.1
SHELL TRENCHES	TOU-LF (H)	100,000	100,000		$98.0	$75.5	235	355	520	$252.8	$343.3	$467.9
HEX PITS	TOU-LF (H)	3,300	3,300		$6.2	$4.8	60	180	320	$7.6	$13.4	$20.1
SANITARY LANDFILL	LF (H/B)		400,000	16,000	$31.0	$23.9	50	125	230	$35.8	$53.7	$78.8
SECTION 36 LIME BASINS	LF (H)/Cap Site	9,727	54,151		$11.0	$8.5	50	125	230	$12.7	$19.1	$28.0
BURIED M-1 PITS	Ex-Situ Solid. (H)	22,000	25,716		$18.0	$13.9	50	125	230	$20.8	$31.2	$45.7
SOUTH PLANTS CENTRAL PROCESSING	TD-Sld(PT)/LF(H)/Cap Site	234,930	282,597	3,669	$85.0	$65.5	60	180	320	$104.7	$183.3	$274.9
SOUTH PLANTS DITCHES	TD (PT)/LF (H/B)	3,411	33,633	23,433	$5.5	$4.2	50	125	230	$6.4	$9.5	$14.0
SOUTH PLANTS BALANCE [Tank Farm]	TD (PT)/LF (H/B)	16,548	134,298	526,715	$52.0	$40.0	50	125	230	$60.1	$90.1	$132.1
BURIED SEDIMENTS	LF (H/B)		16,000	7,900	$3.1	$2.4	50	125	230	$3.6	$5.4	$7.9
SAND CREEK LATERAL	LF (H/B)		15,000	34,000	$9.5	$7.3	50	125	230	$11.0	$16.5	$24.1
SECTION 36 BALANCE OF AREAS	LF (H/B)		79,000	140,000	$28.0	$21.6	50	125	230	$32.3	$48.5	$71.1
BURIAL TRENCHES	LF (H)		27,253		$7.9	$6.1	50	125	230	$9.1	$13.7	$20.1
	TOTAL	1,671,000	3,283,000	3,941,000	$1,020.2	$785.5				$1,352.5	$2,156.1	$3,156.4

▭ = Volume not addressed in DAA; obtained directly from Foster Wheeler.

Notes:

1. Excavations backfilled w/ clean borrow materials and revegetated.
2. Contingency estimate components include unit cost and volume contingency and additional indirects.



All costs adjusted for inflation and contingencies.

Reference;
The HAZRISK Cleanup Report
Prepared for U.S. Department of Energy July 1991

Figure 1